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METHOD AND APPARATUS FOR PREDICTING VEHICLE AIR SYSTEM PERFORMANCE AND RECOMMENDING AIR SYSTEM COMPONENTS

Background of the Invention

The present invention relates to a method and apparatus that are used by vehicle air system designers to predict air system performance in a motor vehicle. The method and apparatus also provide the air system designer with a recommendation for air system components to optimize air system performance for a particular vehicle and its expected vocation. The present invention is described herein with particular reference to vehicle air systems, but those of ordinary skill in the art will recognize that the invention has wider application and can be used to predict performance of air systems found in applications other than vehicles without departing from the overall scope and intent of the invention. It is intended that the method and apparatus of the present invention relate to both vehicle and non-vehicle air systems.

Heretofore, a designer of a vehicle air system has been forced to utilize experience, rules of thumb, past performance observations, and other information in the selection of vehicle air system components such as air compressors, air dryers, filters, and the like. Several developments have made this approach highly undesirable. Pneumatic component manufacturers have demanded that their components be supplied with cleaner and drier air to increase performance. Selection of sub-optimal compressors and dryers results in air that is too moist and/or dirty owing to a compressor duty cycle that is above a recommended threshold.

On the other hand, in an effort to ensure an ample

supply of clean, dry compressed air, the vehicle air system designer may select and air compressor and drier combination that is overly capably for a given application. This, then, needlessly increases the cost and weight of the vehicle.

Also, modern vehicles are being equipped with an ever increasing number of pneumatic components, and some of these additional components demand especially large amounts of compressed air from the vehicle air system. Many designers are simply unfamiliar with these devices and the load that they can potentially exert on a vehicle air system.

Furthermore, conventional methods of selecting air system components for vehicles do not account for variations in use by identical vehicles, i.e., identical buses may have different air system requirements depending upon road conditions, driving conditions, climate, and other variables. Thus, while a designers selection of an air compressor and dryer combination may be appropriate for some potential applications of a vehicle, it may be inappropriate for other potential applications of the same vehicle.

In light of the foregoing specifically noted deficiencies and others associated with convention air system design, a need has been identified for a new and nonobvious method and apparatus for predicting vehicle air system performance and recommending air system components.

Summary of the Invention

In accordance with a first aspect of the present invention, a method of designing a vehicle air system includes using a computer to simulate operation of a proposed vehicle air system over a time period. The proposed vehicle air

system includes an air compressor and a pneumatically operable device. The computer is used to calculate a duty cycle of the air compressor over the time period, thereafter outputs the duty cycle.

In accordance with another aspect of the invention, a method for predicting performance of a vehicle air system includes inputting into a computer data that simulate a proposed vehicle air system, including: (i) data that describe a simulated air compressor of the proposed vehicle air system; and, (ii) data that describe a simulated pneumatically operable device of the proposed vehicle air system. The computer is used to simulate operation of the proposed vehicle air system over a simulation time period. The simulation operation includes: (i) selectively simulating exhaustion of air from the proposed vehicle air system in response to simulated operation of the pneumatically operable device; and, (ii) selectively simulating addition of air to the proposed vehicle air system in response to simulated operation of the air compressor. Data that describe the simulated operation of the proposed vehicle air system are output.

In accordance with another aspect of the present invention, a method for predicting vehicle air system performance includes inputting data that describe a proposed vehicle air system including at least an air compressor and at least one pneumatically operable device. Input data related to a capacity of the proposed air compressor to supply air to the proposed vehicle air system are received, along with input data related to a cut-in pressure of the proposed vehicle air system below which the proposed compressor is considered

operative to add air to the proposed vehicle air system. Input data related to a cut-out pressure of the proposed vehicle air system are also received and describe a pressure above which operation of the proposed compressor to add air to the proposed vehicle air system is considered terminated. Input data are received that are related to a usage rate at which the at least one pneumatically operable device depletes air from the proposed vehicle air system when operated. Input data are received that are related to the frequency of operation of the pneumatically operable device. A period of operation for the proposed vehicle air system is determined, and operation of the proposed vehicle air system is simulated over the period of operation by: (i) calculating data that represent air depleted from the proposed vehicle air system based upon the usage rate and frequency of operation of the at least one pneumatically operable device; and, (ii) calculating data that represent air added to the proposed vehicle air system by the proposed air compressor based upon the cut-in and cut-out pressures. The compressor duty cycle is then determined.

One advantage of the present invention resides in the provision of a new and nonobvious method and apparatus for predicting vehicle air system performance and recommending air system components.

Another advantage of the present invention is found in the provision of a method and apparatus for predicting vehicle air system performance and recommending air system components, wherein a designer inputs proposed air system components and receives an analysis of the performance of the

proposed components for a particular vehicle and vehicle application.

A further advantage of the present invention results from the provision of a method and apparatus for predicting vehicle air system performance and recommending air system components, wherein the impact of accessories, brake system variations, driving habits, climate, and road conditions on the air system can be accurately predicted.

Still another advantage of the present invention resides in the provision of a method and apparatus for predicting vehicle air system performance and recommending air system components, wherein an air system proposed by a designer is analyzed on a period-by-period (e.g., minute-by-minute) basis to assess its likely performance under actual vehicle use conditions.

Still other benefits and advantages of the present invention will become apparent to those of ordinary skill in the art to which the invention pertains upon reading and understanding the following specification.

Brief Description of the Drawings

The invention comprises a variety of components and arrangements of components, and a variety of steps and arrangements of steps, preferred embodiments of which are disclosed herein with reference to the accompanying drawings that form a part of the specification and wherein:

FIGURE 1 diagrammatically illustrates an apparatus for predicting vehicle air system performance and recommending air system components;

FIGURE 2 is a flow chart that illustrates a method

for predicting vehicle air system performance and recommending air system components in accordance with the present invention;

FIGURES 3A and 3B together define a flow chart that discloses a method of simulating use of a proposed vehicle air system, calculating the duty cycle and other performance characteristics of the proposed air system, and recommending air system components in accordance with the present invention; and,

FIGURE 4 illustrates a preferred output page resulting from the method in accordance with the present invention.

Detailed Description of Preferred Embodiments

Referring now to the drawings, wherein the showings are for purposes of disclosing preferred embodiments of the invention and not for limiting the invention in any way, an apparatus formed in accordance with the present invention is illustrated in FIGURE 1. The apparatus preferably comprises a general purpose computer **10** programmed to carry out a method for predicting vehicle air system performance and recommending air system components in accordance with the present invention. In a most preferred embodiment, the general purpose computer **10** is an IBM compatible personal computer of modern design, having at least a Intel Pentium® class microprocessor with at least 16 megabytes of random access memory, a mass storage disk drive **12** having at least 1 gigabyte of capacity, a color video monitor **14**, a keyboard **16**, a pointing device such as a mouse **18**, and a printer **20**. Other

more or less powerful computer systems may be used, and other types and brands of computer systems can be employed (e.g., Apple® brand computer systems), without departing from the overall scope and intent of the present invention.

Referring now to FIGURE 2, a method for predicting vehicle air system performance and recommending air system components in accordance with the present invention is disclosed. The method is preferably carried out in the general purpose computer **10** after same has been programmed in accordance with the method.

In a first step **S1**, a user of the computer **10** enters general information concerning the vehicle on which the proposed air system is to be used. This is merely for identification purposes and includes information such as, e.g., the make, model, vocation, and anticipated customer for the vehicle. This information is stored in the computer **10**.

In a second step **S2**, the user enters into the computer **10** information about the proposed air charging system of the vehicle. Preferably, this includes information on a proposed compressor, information on a proposed air dryer, information on the engine that is to drive the proposed compressor, the volume of the air system, and information on the expected vehicle operation. Each of these is described below in further detail.

In step **S2**, a user must supply information on a proposed air compressor. Most preferably, the user simply uses the pointing device **18** of the computer **10** to select a compressor from a predefined list. For each compressor that may be selected by the user, the computer **10** has access to a

database or the like stored on the mass storage device **12** that supplies the computer **10** with operational characteristics of the compressor. For example, the output of each compressor at different speeds of the driving engine must be known so that this information can be used to derive the compressor's input to the air system of the vehicle as described below. Furthermore, after a compressor is selected from the compressor list, the user must input a cut-in pressure and a cut-out pressure for the selected compressor that govern cycling-on and cycling-off of the compressor. The cut-in pressure is the pressure of the vehicle air system where the selected air compressor will cycle "on" and build air into the vehicle air system. Conversely, the cut-out pressure is the pressure of the vehicle air system where the selected compressor will cycle "off" and no longer build air into the vehicle air system.

As noted, the user must also select a type of air dryer from a predefined list or may enter "other" for a dryer not set forth on the list. Again, for each air dryer on the predefined list, the mass storage device **12** of the computer contains information concerning the purge volume of the dryer and source of purge air, i.e., from a volume held by the dryer or from the vehicle air system. The purge volume is the amount of air passed through the dryer to purge moisture therefrom. This purge air can be taken from the vehicle air system or from another reservoir dedicated for this purpose. If the user selects "other" for a proposed air dryer, the user will be required to supply all of the foregoing, i.e., the purge volume of the air dryer, or if the dryer purges from the vehicle air system, the vehicle air system pressure drop

caused by each purge operation.

Also in step **S2**, the user will be required to enter information concerning the expected operation of the vehicle. This preferably includes: (1) the average time between vehicle stops (e.g., 10 minutes or 1 hour (60 minutes); (2) the average number of stops per day (e.g., 40); (3) the average number of parking brake applications per day (e.g., 6); and, (4) the average number of brake applications between stops (e.g., 10). From items (1) and (2) above, the vehicle operation duration is derived, e.g., a stop every 10 minutes with 40 stops per day = 400 minutes of operation = 6.67 hours of operation per day. Item (3) is used to account for air used by the vehicle air system during parking brake application and release. Item (4) accounts for air consumed from the vehicle air system by brake activity between complete vehicle stops, e.g., light brake applications for speed control, cornering, and the like.

A user must also supply information on the vehicle engine that is used to drive the air compressor. Preferably, the user selects an engine type from a predefined list and indicates whether the engine is normally aspirated or turbo charged. If turbo charged, the user must enter the boost pressure. Regardless of the engine selected, the user must enter an average engine speed (RPM) at which the engine is operated between stops. This information is used to determine the average air building ability of the air compressor selected by the user.

A user is also prompted to enter a total volume of the vehicle air system. A user can simply select a "minimum volume" button using his/her pointing device **18**. When this

minimum volume button is selected, a minimum system volume value (as prescribed by air system safety standards) is used in the analysis described below, wherein the minimum volume is equal to the volume of the vehicle braking system.

A step **S3** of the subject method requires a user to enter information concerning the braking system of the vehicle being analyzed. Specifically, the user is required to enter relevant information concerning the front, rear, tag axle (if vehicle is equipped with a tag axle), and parking brake systems. In a most preferred embodiment, for each of the applicable front, rear, and tag axle brake systems, the user must enter a chamber type (preferably selected from a predefined list including, e.g., Type 6, 9, 12, 16, 20, 24, 30, and 36 chambers). For each chamber type set forth in the predefined list, an associated chamber volume is stored on the disk drive or other mass storage device 12 of the computer apparatus **10**. After a user selects one of the chamber types from the list, the associated chamber volume value is displayed to the user, and the user can override the displayed value if desired. Also, a user can select chamber type "other" from the predefined list, in which case the user must enter the associated chamber volume. The user is also prompted to enter the length and diameter of the brake lines leading to the selected type of chambers. Finally, the user is prompted to enter the number of the selected type chambers found on the axle in question. From the foregoing, the total brake system air volume for each axle is derived and displayed to the user. Also, once the user has entered all requested values for all axles, a total brake system air volume is derived and displayed to the user.

The user is then required to enter information concerning the parking brake system connected to the vehicle air system. In particular, the user must indicate whether the vehicle is equipped with a spring brake parking brake or with a DD-3 based parking brake system. These place different air demands on the vehicle air system.

In a step **S4**, the user also must input into the apparatus **10** information relating to all auxiliary systems connected to the vehicle air system. Auxiliary systems include, e.g., suspension, kneeling, wiper, door, seats, shift, and other similar air-powered vehicle systems. A pre-defined list of potentially used auxiliary devices/systems is displayed to the user, and the user can use the pointing device **18** to select those that are found on the proposed vehicle air system being analyzed. For each auxiliary system selected, the user is prompted to enter additional information so that the demand on the vehicle air system for each auxiliary system can be determined.

One of the available choices on the predefined list of auxiliary devices/systems is entitled "air leak" or the like. By selecting this, the user can input information concerning the expected amount of air loss from the vehicle air system due to leak conditions. It is preferred that this air loss due to air leakage be treated as an auxiliary device/system, with identical inputs as described below.

Specifically, for each auxiliary system selected to be included in the analysis, the user is required to enter at least: (1) the average amount of air consumed by the auxiliary system/device during its operation; and, (2) the volume from which the air loss occurs. Concerning item (1), the average

air consumed, the user can enter this value using one of three different parameters -- (a) pressure/volume in terms of pounds per square inch(psi) or the like; (b) flow rate in terms of cubic feet per minute (cfm) or the like; or, (c) a pressure drop rate in terms of psi/minute. Thus, regardless of the air usage rate units known by the user for a particular auxiliary system/device, the user will be able to enter this information without performing a units conversion operation. Concerning item (2) above, the volume from which the air loss occurs, the user can also select one of three predefined volumes -- (a) the overall vehicle air system volume; (b) a separate volume (i.e., reservoir) of the auxiliary system/device; or, (c) both the overall vehicle air system volume and a volume maintained by the auxiliary system/device. In the cases (b) and (c), where the air loss occurs at least partially from the from auxiliary system/device, the user is prompted to enter the auxiliary system/device volume.

For an auxiliary door system, in particular, the user must indicate if the vehicle is equipped with a brake interlock system, i.e., a system that automatically operates at least part of the vehicle brake system when the door operated. If the user answers "yes," the user must also indicate whether the front, rear, or both brake systems are activated for the interlock operation, and the pressure at which the brake system is activated.

Those of ordinary skill in the art will recognize that air usage by auxiliary systems/devices can be measured in different ways. For a suspension system, the preferred air usage rate is air used per inch of suspension travel. For an auxiliary wiper system, the preferred air usage rate is

expressed in terms of air used per minute of operation. For a kneeling, door, shift system, or other system where a discrete event is carried out by the auxiliary system, the preferred air usage rate is the air used per event, i.e., air used per kneeling cycle (down/up), air used per door activation cycle (open/close), and air used per shift, respectively. Thus, for these auxiliary system where a discrete event occurs, the user is also prompted to enter the average number of events per day expected for the vehicle being analyzed.

If the user desires to include a type of auxiliary system/device that is not set forth on the predefined list of same presented to the user, the user can use the pointing device **18** to select "other" and is prompted to supply all of relevant information noted above. Furthermore, the user can assign a name to the "other" selection so that it will thereafter form a part of the predefined list of auxiliary devices/systems presented to the user. Examples of other auxiliary devices that may not be found in the predefined list include air starters, lift mechanisms, and the like.

As noted above, step **S4** also comprises supplying information about the expected air leakage or loss in the vehicle air system being analyzed. The information supplied is identical to the information supplied for other auxiliary systems not of the discrete event type. A rule of thumb for this loss is 1 psi / minute, and this value can be supplied as a default if desired.

In a step **S5**, the user enters information concerning the type of road conditions expected to be encountered by the vehicle being analyzed. Specifically, the

user is preferably prompted to select one of at least three predefined values for the average expected amount of suspension displacement, e.g., 0.5 inch, 1.0 inch, or 1.5 inch. This parameter describes the average amplitude of the suspension travel. Preferably, the user is also prompted to select one of at least three different values that describe the average number of suspension activations per hour, e.g., 2 (smooth roads), 10 (average roads), or 60 (rough roads). This parameter describes the frequency of suspension activations. This information is used to determine air loss due to suspension activations and seat activations.

A step **S6** comprises the user entering information into the apparatus **10** that describes typical brake application pressure. Preferably, the user is prompted to select one of at least three different predefined average brake application pressures, e.g., "Hard" (22 psi or 1.5 bar), "Medium" (15 psi or 1.0 bar), or "Light" (10 psi or 0.7 bar). This, of course, will affect the amount of air used by the primary brake system of the vehicle.

A step **S7** comprises the user entering information into the apparatus **10** that describes typical environmental conditions expected for the vehicle. Preferably, here again, the user is prompted to select one of at least three different average predefined environmental descriptions, e.g., "Wet" (wipers operated 75% of vehicle operation time), "Normal" (wipers operated 30% of vehicle operation time), or "Dry" (wipers operated only 1% of vehicle operation time). This parameter will affect the amount of air used by the auxiliary air wiper system, if present on the vehicle according to

information supplied by the user concerning auxiliary devices/systems as noted above.

A step **S8** comprises using the computer **10** in accordance with the method described herein to calculate the air consumed by the proposed vehicle air system being analyzed during a typical period of operation, and generating a summary report of same, including recommended modifications, if any are required, to the vehicle air system components proposed by the user. Finally, a step **S9** comprises the user reviewing the analysis and summary report.

Referring now to FIGURES 3A and 3B, a preferred implementation of step **S8**, via sub-steps **S8-1** through **S8-30**, is disclosed. In general, all information input by a user is used to simulate a "day in the life" of the proposed vehicle air system. This, then, allows information such as the compressor duty cycle, total number of dryer purges, the air treated per cycle, the volume of air used by each device, and the percent of air used by each device to be determined. Although the following analysis as described herein uses minutes as the unit of time, those possessed of ordinary skill in the art will recognized that other time periods can be used without departing from the overall scope and intent of the present invention. Furthermore, while the following process is described in detail, conventional flag and counting variables and other conventional computer programming techniques are omitted for clarity and ease of appreciating the present invention.

Steps **S8-1** and **S8-2** comprises calculating system volume and pressure loss, respectively, for one minute of operation (assumed to be one device activation) of each device

that forms a part of the vehicle air system, i.e., the brake, suspension, and auxiliary systems, described above. The sub-steps **S8-1,S8-2** calculate the amount of air used per minute or by each activation of each device and derive the volume and pressure loss from the vehicle air system resulting from the air loss. These values for each device are stored on the mass storage device **12** in a look-up table or the like for later use as needed. For the devices where a discrete operation is performed, i.e., a shift, a kneel/unkneel cycle, door open/close cycle, a parking brake application, a brake application for vehicle stop, etc., it is assumed that one cycle is carried out in a minute. For the brakes, the air used will depend upon the typically brake application pressure entered by the user in step **S6**. For the suspension and seats, in step **S4**, the user has entered the amount of air used per inch of suspension travel and per seat activation and, in step **S5**, the user has entered the average amplitude of suspension travel and the average frequency of suspension activation. From this information, the air used by the suspension and seat systems during one minute of operation is derived. For wipers, air leak, and other auxiliary devices, the volume and pressure loss resulting from one minute of operation is derived from or directly available from the usage rate information entered by the user in step **S4**.

A step **S8-3** comprises calculating, in minutes, the total operational time of the vehicle on which the air system is in use. As noted above, this is preferably derived based upon the number of stops, and the time between stops.

A step **S8-4** calculates the time, in minutes,

between applications for each device. Various methods are used to determine this value. For devices where there is a discrete operation, a brake application for a vehicle stop, a brake application for speed control, a parking brake application, a kneeling cycle, a door open/close cycle (with or without brake interlock), or the like, the time between applications of the device is determined by equally spacing the estimated number of events over the calculated operation time of the vehicle, e.g., if the vehicle is operated for 100 minutes per day, with 10 door cycles per day, the time between door cycles is calculated as 10 minutes. For the suspension, the step **S8-4** calculates the time between suspension activations based upon the input of suspension activations per hour input by the user in step **S5**. For wipers, the step **S8-4** derives the time between applications for the wipers based upon the environmental conditions input by the user in step **S7**, e.g., for "wet" conditions the wipers are assumed to be operated 75% of the vehicle operation time, for "normal" conditions the wipers are assumed to be operated for 30% of the vehicle operation time, and for "dry" conditions the wipers are assumed to operate only 1% of the vehicle operation time. Thus, for example, if the vehicle operation time is derived as 100 minutes in step S8-3, and "normal" environmental conditions are input by the user in step **S7**, there will be 30 wiper applications during the 100 minutes of operation and these are assumed to be evenly spaced over the vehicle operation duration, i.e., one wiper application every three and one-third minutes (normal number rounding is used to set three and one-third minutes equal to 3 minutes).

As noted, the total operation time of the vehicle

is calculated in step **S8-3**. This "total operation time" variable is decremented during the analysis described below until it reaches zero. Specifically, a step **S8-5** checks to see if the total operation time of the vehicle equals zero. If not, the analysis continues with a step **S8-6** that selects a device from a list of all possible devices. A step **S8-7** determines if the device selected in step **S8-6** has been included on the system proposed by the user. If not, a step **S8-8** checks to see if the step **S8-6** has selected every possible device and, if not, control returns to step **S8-6** for selection of another potentially included device.

If, on the other hand, the step **S8-7** determines that the user has included the selected device in the analysis, control passes to step **S8-9** that determines if the selected device is due for an activation according to the time between its applications derived in step **S8-4** above. Specifically, each device is associated with a respective variable "device time" that is initially set at zero and thereafter compared to the time between applications determined for that device in step **S8-9**. If the device is not due to operate, i.e., the device time has not yet reached the value of the time between applications for the device, control returns to step **S8-8**. However, if the selected device is due to operate, a step **S8-10** obtains the device's system volume loss (determined in step **S8-1**) and adds this to a running total variable (referred to herein as "device total volume loss") that represents the air volume loss for the minute of

operation being analyzed. Furthermore, a step **S8-11** adds the device's system volume loss to a second running total variable (referred to herein as "cycle total loss") that represents air volume loss over the entire operation time of the vehicle. A step **S8-12** subtracts the pressure loss from operation of the device from the variable "system pressure"(which defaults to the compressor cut-out pressure at the beginning of step **S8**). Thus, the pressure of the vehicle air system is always known. The step **S8-13** re-sets the device time variable to zero (the device time variable for each device defaults to zero at the beginning of step **S8**) which is, again, the variable that determines whether the device is to be operated at a given vehicle operation time. Finally, control returns to step **S8-8** which determines if, for a particular minute of the vehicle's operation, all possible devices have been examined. If not, control returns to step **S8-6**, otherwise, control passes to step **S8-14**.

The step **S8-14** compares the variable "system pressure" to the compressor cut-in pressure input by the user in step **S2**. If the system pressure is not less than the cut-in pressure, the vehicle air system does not require the compressor to build air into the system, so control passes to step **S8-15** that decrements the "total operation time" variable by one minute and then to step **S8-16** that increments the "device time" variable associated with every included system device. Control then returns to step **S8-5** described above.

If, on the other hand, step **S8-14** determines the

pressure of the vehicle air system is less than the cut-in pressure, control passes to step **S8-17** that determines what volume of air the compressor must supply to add 1 psi to the vehicle air system. A step **S8-18** compares the system pressure to the cut-out pressure and also compares a variable "build time" (which is reset to zero as control passes from step **S8-14** to **S8-17**) to 60 seconds. The variable "build time" is a running total, in seconds, of the time a compressor has been building air into the vehicle air system for a given air charge cycle. If the system pressure is less than the cut-out pressure and the variable "build time" is less than 60 seconds, a step **S8-19** determines how much air is delivered from the compressor to the vehicle air system for one second of compressor operation based upon the compressor speed (derived from the average engine RPM and other engine information entered by the user in step **S2**), the compressor inlet pressure, and the present pressure of the vehicle air system. A step **S8-20** determines the system pressure increase that would result from addition of the air volume determined in step **S8-19** to the system volume. A step **S8-21** adds the pressure increase determined in step **S8-20** to the system pressure, a step **S8-22** increments the build time variable by 1 second, and control returns to step **S8-18**.

When the step **S8-18** determines that the system pressure has reached the cut-out pressure or the build time variable has reached 60 seconds, control passes to step **S8-23** which adds the total volume of air delivered by the compressor during the build time (the build time is either a 60 second

period or less if the cut-out pressure is reached before 60 seconds of build time is reached) to a variable "total air treated" which is initially set to zero at the beginning of step **S8**. The "total air treated" variable represents the total volume of air delivered by the compressor over the total operation time of the vehicle. A step **S8-24** increments a "charge cycles" variable that initially is set to zero at the beginning of step **S8**. The variable "charge cycles" represents the number of times the compressor has been used to build air into the vehicle air system over the total operation time of the vehicle. Control then passes to step **S8-15** described above. Also, the value of the variable "build time" at the end of each compressor charge cycle is added to a variable "total build time" before being reset to zero for later duty cycle and average charge time calculations.

Eventually, the total operation time of the vehicle will equal zero and the step **S8-5** will transfer control to step **S8-25** that calculates the compressor duty cycle, i.e., the percentage of the total operation time that the compressor was used to build air into the vehicle air system. A step **S8-26** calculates the average build time required to reach the cut-out pressure. A step **S8-27** determines the average unloaded time for the compressor, i.e., the average amount of time that passed between charge cycles of the compressor. A step **S8-28** calculates the total air treated per cycle, i.e., the total air supplied from the compressor to the air dryer per each cycle of the compressor. A step **S8-29** uses the total air treated number from step **S8-28** and the total air used by

each included device over the time of operation to determine the percentage of the total air used by each device.

Finally, a step **S8-30** examines the duty cycle calculated by step **S8-25**. If the duty cycle is below a first threshold, the compressor and air dryer combination proposed by the user in step **S2** is approved. If the duty cycle is above the first threshold, an extended purge air dryer is recommended. If the duty cycle is above a second threshold that is higher than the first threshold, but below a third, highest threshold, the customer is advised to use an additional filter upstream relative to the air dryer. Finally, if the duty cycle is above the third threshold, a larger capacity compressor/dryer combination will be recommended.

FIGURE 4 is an example of a preferred output page that is displayed to a user on the video monitor **14** and printable to a user on the printer **20** to supply the user with all relevant information concerning the proposed vehicle air system as described above. In particular, as shown in FIGURE 4, the preferred output page includes at least the information obtained from steps **S8-25** through **S8-30**.

The invention has been described with reference to preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding specification. It is intended that the invention be construed as including all such modifications and alterations insofar as they fall within the scope of the following claims and equivalents.